A GENERAL PHYSIOLOGY

FOR HIGH SCHOOLS

BASED UPON THE NERVOUS SYSTEM

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BY

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"*The physiology of the nervous system is emphatically the physiology of the future.*" — MICHAEL FOSTER, M.D., F.R.S.

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PREFACE

THE effort has been made in this book to unify the study of the parts and the functions of the human organism by the application of approved pedagogical and scientific principles. The teaching of any science proceeds logically from that which is known to that which is not known. Physiology is one of the earliest of the natural sciences to be presented for formal study in school. In respect to man's organism the one sort of knowledge absolutely original and elemental is *consciousness* — conscious motion and sensation. This it is that forms the most apparent difference between the two kingdoms which manifest the phenomena of life. It is characteristic of animals to possess consciousness, volition, feeling. Plants are, to all appearance, devoid of them all.

Hence this study of human physiology is made to begin with that part of the body which is the organ of consciousness — the *nervous system.* The pupil knows that he thinks and feels and wills and moves, and he studies physiology in order to understand the apparatus by which these wonders are accomplished. He is here given first (after a few preliminary definitions) a brief sketch of the parts composing the nervous system. Next he studies those physical operations into which consciousness enters as an essential quality, and becomes familiar with the organs of motion and sensation. This leads naturally to consideration of the provision for the sustenance of those organs — nutrition in its comprehensive sense. Finally the student comes to a more detailed examination of the mechanism for the conscious activities of the human being.

Whatever may be true of philosophers, the infant begins the study of physiology at the point here suggested, and follows a method in harmony with this plan. More than one practical teacher has worked out a similar method through years of experience in the class room. By making the nervous system (the center and core of all animal life) the leading thought throughout, a unity of impression is secured,

the actual connection of every vital process with the one nervous system becomes obvious, and the emphasis is placed where it properly belongs. It is believed that this plan has advantages also for the student of general biology. It emphasizes the one grand, obvious distinction between plants and animals. To students of psychology it will likewise commend itself. Because of prevalent ignorance of the nervous system and its due predominance in the animal economy, psychologists have been forced to become physiologists in order to build across the gap, left by the ordinary manner of treatment, between physiology and psychology.

Care has been taken to make no statements not in accord with established science, but no effort is made to introduce the newest conjectures. The necessary limitations of a school text-book have been kept in mind as well as the degree of mental development of those for whom the work is designed.

It is believed that the instruction respecting alcoholic drinks and narcotics, while complying with the requirements of recent legislation in the various states, will be found to be based upon rational and scientific principles, and to be placed before the student in a manner to win the assent of his reason rather than to create a mere prejudice which further knowledge might overthrow. Nothing is gained by overstatement, and it is always safe to tell the simple truth, for nothing will so surely foster right living as a knowledge of the truth.

The writer has had much assistance from experienced and competent teachers and physicians. Dr. A. W. Alvord (M.D., University of Michigan) of Battle Creek, Michigan, has kindly revised the hygienic portions of the book. Mr. H. W. Norris, A.M., Professor of Biology in Iowa College, has read and criticised the whole of the manuscript. All of the experimental work has been prepared by him and will be found of especial value. Many of the illustrations used are such as are commonly found in schoolbooks treating the subject of physiology, but a large number have been adapted from cuts in recent advanced works, mainly those by Morris, Spalteholz, and Van Gehuchten; while numerous other drawings expressly for this work have been made by Mr. E. W. Atherton under the direction of Professor Norris.

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PART I

INTRODUCTION

It is customary to divide the study of the human body into three departments: (1) *Anatomy*, which is the science that describes the structure of the body; (2) *Physiology*, or the science of the functions, or uses, of the various parts of the body, and (3) *Hygiene*, or the science of health, which treats of the care of the body and all its parts for the purpose of maintaining the whole in its best condition for usefulness and enjoyment. The term *Physiology*, as applied to a schoolbook, however, is often used to include all three of these lines of study.

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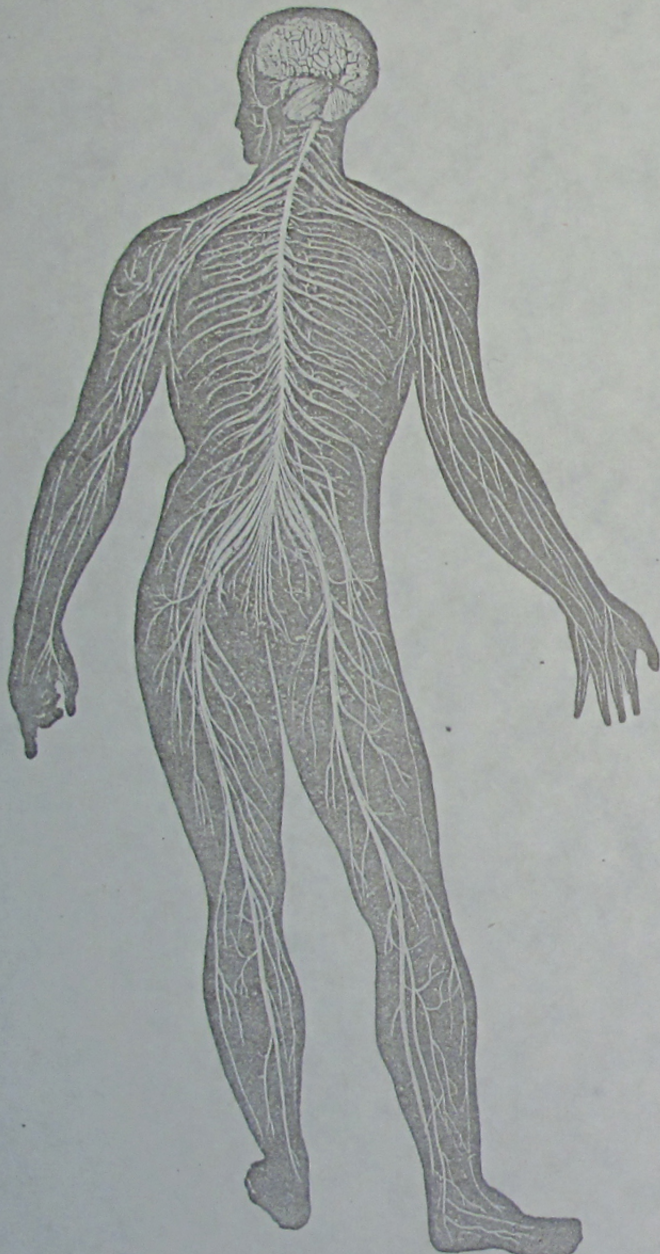

Fig. 1. – The nervous system.

CHAPTER I

MATTER AND CELLS

1. Living and Lifeless Matter. — What matter is we are not yet able to say, but as it exists in our world it may be separated into two great divisions, — living matter and lifeless matter. So far as present knowledge goes, these two sorts of matter are wholly distinct the one from the other, and lifeless matter never becomes living matter except under the influence of matter already living. The same substances are indeed found in the two sorts of matter, and when living matter is killed, or becomes lifeless, no change can be discovered in its weight. That mysterious something called *life* is therefore not material, and living matter may be said to be only ordinary lifeless matter existing in a different state or condition.

2. Chemical Elements. — A substance which cannot be divided into two or more different kinds of matter is called a *chemical element*, or a simple substance. All others are called compound substances. Matter is separated into its elements by processes which affect the molecules or the atoms of which it is composed, that is, by chemical analysis.

A *molecule* may be defined as the smallest particle of matter which exists alone and retains most of the properties of the mass of the substance. An *atom* is one of the ultimate particles of which a molecule is composed. The

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molecules of chemical elements are composed of atoms of the same kind. Compound substances have atoms of different kinds. There are as many kinds of atoms as of elements. Both atoms and molecules are too small to be seen even with powerful microscopes.

A drop of water may be divided mechanically into many small portions, and each part will retain all the characteristics of the original drop. But when the chemist separates the oxygen and hydrogen which together make up the drop of water, he has no longer any matter which resembles water, but instead two kinds of gaseous matter of entirely different properties. The water has been resolved by chemical analysis into its chemical elements.

Chemical elements unite in different proportions with one another to form a great variety of substances. About seventy-five elements have been isolated by chemists, but only a few of them are known to enter into the structure of animal bodies. These are carbon, oxygen, hydrogen, nitrogen, sulphur, phosphorus, chlorine, fluorine, silicon, potassium, sodium, lithium, calcium, magnesium, iron, and manganese. As a rule these elements exist in the body in some sort of combination with one another.

3. Protoplasm is a name given to living matter. It is a clear, jellylike substance containing minute grains. As protoplasm, it cannot be chemically analyzed, because the process of analysis destroys its vitality so that it is no longer protoplasm, but merely dead, lifeless matter. The one essential thing about protoplasm is that it is alive; dead protoplasm is a contradiction in terms. It has been called "the physical basis of life," because without it life does not exist, and with it there is always life. But the material of which protoplasm is composed is found, when

analyzed after it has ceased to live, to be highly complex. A large part of its weight is *water*, while its solid portion is chiefly composed of *proteids*. These are substances found in many foods, white of egg being a familiar example. They contain carbon, hydrogen, oxygen, and nitrogen.

4. The Cell (Fig. 2). — All living bodies, both plants and animals, are found to consist of cells. Cells are the ultimate units of which living beings are made up, just as bricks are the units of which a brick wall is composed. A *cell* is a microscopic bit of protoplasm, with or without an inclosing wall, having suspended within it a rounded body of denser material called the *nucleus*. It may be living apart, or may form one of the units of an organism. Plant cells have usually the cell wall, but an animal cell may be only a naked speck of living matter. Free cells tend to assume a round shape, but under pressure they may take almost any form.

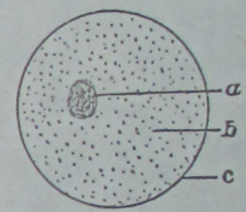

Fig. 2. — Diagram of the parts of a cell.

a nucleus.
b cell body or protoplasm.
c cell wall.

5. The cells of the human body vary in size from $\frac{1}{300}$ to $\frac{1}{3000}$ of an inch in diameter. All animals begin their existence as single cells, and the life of any animal is the sum of the activities of all its separate cells, while its physical structure consists of the cells themselves and the intercellular matter which they produce, together with the various lifeless substances which they deposit within themselves.

6. Essential Properties of Cells. — All living things possess two properties without which they cannot exist.

One of these properties is *nutrition*, — using the word in its broader sense to include the double process of taking

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in material from outside and building it into the bodily structure, — that is, the making of complex chemical compounds out of simpler ones; and the breaking down, or reducing to simpler forms, of compounds already formed. The former results in growth or repair of cell substance, and is the storing up of energy; the latter is the setting free of energy, and the production of waste material to be removed as no longer valuable. Nutrition includes all the chemical changes which take place in living matter.

The other essential property of living bodies is the power of *reproduction*, or of giving rise in some way to living beings like themselves.

The first of these properties, nutrition, belongs to every individual cell, to every plant, and every animal, as necessary to its own continued existence. The second, reproduction, is needful only for the continued existence of the race, and is in some cases possessed only by certain individuals of the race. Single cells are, however, capable of giving rise by self-division to other cells like themselves.

Life is sustained by the ceaseless exercise of the two powers of nutrition and reproduction.

7. Other Properties of Living Cells. — Certain other properties are found to exist in most cells in the body, for example, in the white corpuscles of human blood, which are clearly defined nucleated cells.

These are *contractility*, or instability, that is, the power of changing form without the application of pressure; *irritability*, or the power of vigorous action under stimulus, as, for instance, when the blood cells contract under the influence of electricity; *conductivity*, or the power of passing on to distant parts of the cell the influence exerted by a stimulus upon a single point; and *coördination*, or the capacity in all the parts to work together in definite

direction and with regulated strength to accomplish an end, as when a particle of material suitable for building up a cell is drawn in and used for that purpose.

8. Plants and Animals. — No naturalist can at the present day place his finger upon a line of separation and say: All living things upon this side are plants; all upon that side, animals. It is, indeed, easy to distinguish the higher forms of animal life from the higher forms of plant life, and the most striking difference is that the animal possesses the power of spontaneous movement, while the plant is rooted to one spot. Other distinctions appear as the two forms of life are studied. For example, both are dependent for their continued life and growth upon the food which is supplied from without themselves; but plants (the fungi excepted) subsist mainly upon carbon dioxide, water, and mineral salts, while animals live upon water and those chemical compounds which have formed part of living bodies, that is, organic materials. Animals cannot use mineral substances as food except as they are mixed with organic matter. But the simplest forms of plant and animal life cannot be distinguished with positiveness from each other. Both consist of single protoplasmic cells, and it is not possible to show that the protoplasm of one is essentially different from that of the other.

As animals rise in the scale of being, however, they are found to develop, as plants do not, a nervous system of ever-increasing complexity and importance. Hence man, as an animal, may be said to be distinguished from all other animals by the superiority of his nervous system; and all the other parts of the human body may be considered as created simply to minister in some way to that superior portion of the human frame which is the direct agent or instrument of the highest manifestations of life.

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9. The Difference between Plants and Animals in Respect to Stimulus. — Living animal cells possess the property of irritability or excitability, that is, some change in their composition results from the action of *stimulus*. Vegetable cells also possess this property in some degree. But it is found that, as in the processes of development more and more complex forms of plant life appear, the plant does not develop special organs for the transmission of stimulus. In the animal kingdom, on the other hand, a striking difference appears. In one of the lowest known representatives of animal life — the *amœba* (Fig. 3, p. 16), which is a mere microscopic lump of naked protoplasm — each minute particle of the protoplasm appears to respond to a stimulus and to transmit it to the adjacent particles, there being no distinction of parts or functions in the single cell. But in the next higher division of animals, the corals, sea anemones, etc., the rudiments of a nervous system are visible, and some division of sense organs appears. It is probable that nervous impressions are received first in but a single form, while a gradual and uninterrupted development of the senses follows as we rise in the scale. That is, one of the lower animals may be said to have but one sense, touch, or a general sensibility, — it receives but one kind of sense impression from influences which higher animals recognize as diverse, — while higher animals may distinguish two or more kinds of impression, and so on. It should be noticed that the common division of senses into touch, taste, smell, sight, and hearing is somewhat arbitrary, even man not being always able to discriminate, for instance, between taste and smell, while certain sensations are recognized, such as perception of temperature and of pain, which do not strictly belong to any of the "five senses" so called.

Suggestions regarding the Practical Work

The amount of illustrative experimental work in physiology that can be done in a high school depends chiefly upon two factors: the material equipment of the school and the tact of the teacher.

Vivisection doubtless has its place, but not in the public schools. Ordinary dissections sensibly performed can be made a successful part of class work in most of our high schools, but occasionally deference to public opinion will require that the dissections be performed only by the teacher, or possibly not at all.

No attempt is made in this book to give detailed directions for dissecting, nor for the preparation of material for study with the compound microscope. It is assumed that a teacher of advanced physiology has received some preliminary training in anatomy and microscopical methods. If so, then suggestions will be far better than specific directions.

It is not expected that all the experiments will be performed by a class. When a compound microscope is not available, some of the exercises must necessarily be omitted. It is believed, however, that all the demonstrations, dissections, and experiments can be performed in any school of moderate equipment. A great mistake is made when much apparatus is interposed between the student of elementary science and the objects of his study. The teacher should make sure that the illustration is not substituted for the idea that it is intended to explain. In some instances conditions will require that the teacher perform most of the work of an experiment, but as far as possible the pupil should himself be responsible for each detail.

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DEMONSTRATIONS AND EXPERIMENTS [1]

1. *Amœba.* — The amœba is not always easily obtained. If débris of water plants be kept in shallow dishes of water for several days, there can usually be found specimens of amœba in the scum that forms on the surface of the water, or in the ooze that collects at the edges and bottoms of the dishes. On mounting some of the material on a glass slide and examining with the compound microscope, there may be seen small, irregular, transparent masses of a jellylike nature moving along very slowly with a rolling or flowing motion (Fig. 3). Attention should be given to the constantly changing form of the animal, which thus exhibits a fundamental characteristic of protoplasm, *instability*. If, when an amœba is fully extended, sending out processes, *pseudopodia*, from the main part of the body, the slide be gently tapped, the animal will be seen to contract quickly into a rounded mass, showing another characteristic of protoplasm, *irritability*, or the capacity of response to stimulus.

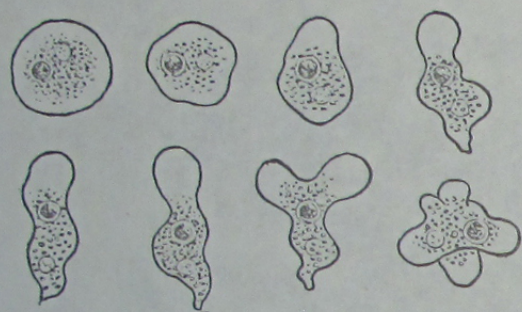

Fig. 3. — Amœba in eight successive stages of movement.

2. *White Blood Corpuscles.* — If a drop of fresh human blood, or preferably of frog's blood, be mounted on a glass slide and examined with the compound microscope, among the numerous red corpuscles may be seen a few transparent ones (Fig. 4). On remaining undisturbed for some time they change in shape, or even migrate, in a manner similar to that of the amœba. Fresh blood may be obtained by pricking the finger with a sterilized needle, and by decapitating or pithing a frog.

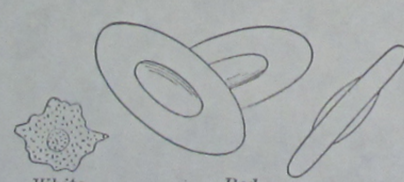

Fig. 4. — Blood cells (corpuscles) of frog.

[1] *Note to Teachers.* — The demonstrations and experiments should precede the recitation of the lessons which they illustrate. The pupil should not be required to describe the brain, for example, until he has studied the dissected organ itself.

3. *Movements of Protoplasm in Plants.* — The phenomena of protoplasmic movements can be observed in a variety of plants. The Stoneworts, *Chara* and *Nitella*, and the stamen hairs of the Spiderwort, *Tradescantia*, furnish some of the best examples. In all these the protoplasm is inclosed in a cell wall, and when observed with the compound microscope is seen to exhibit streaming movements and circulation of particles in the contents of the cell. The response of protoplasm to changes in temperature can be very easily shown by placing the slide on a warming stage upon the microscope stand as shown in Fig. 5. When the warming stage is heated, the protoplasmic movements are seen to increase in rapidity up to a certain point. As it cools, the movements become slower.

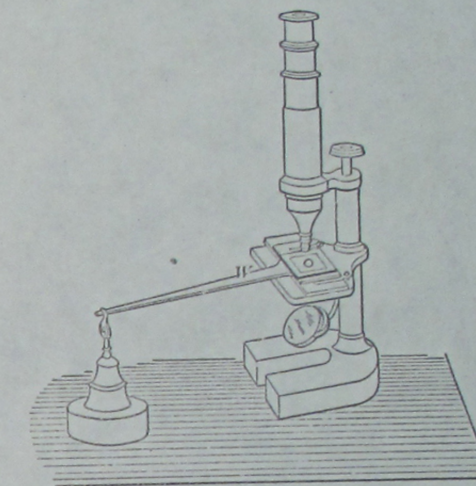

Fig. 5. — Compound microscope with simple warming stage (*W*) attached.

4. *Properties of Protoplasm in Muscle.* — In some animals the various tissues retain their vitality and properties for a considerable time after the death of the individual animal. The common frog furnishes us one of the best examples of this. If a frog's gastrocnemius muscle with sciatic nerve attachments (Fig. 6) be dissected out (see Figs. 7 and 8) shortly after decapitation of the animal, it will retain its properties for a considerable length of time, if kept well moistened with normal salt solution (0.75 per cent solution of common salt). If the nerve be cut with sharp scissors a contraction of the muscle occurs. Touching the nerve with a red-hot needle produces a similar contraction

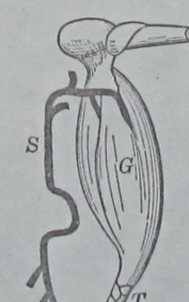

Fig. 6. — Nerve-muscle preparation.

F femur.
G gastrocnemius muscle.
S sciatic nerve.
T tendon (*tendo Achilles*).

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